Our Nature (2010) 8:131-138

Aquatic Oxygen Uptake of the Freshwater Dual Breathing Featherback, *Notopterus notopterus* (Pallas) in Relation to Body Weight

R. Kumari, P.K. Roy and T.K. Ghosh*

Ichthyology Research Laboratory, Post-Graduate Department of Zoology, T.M. Bhagalpur University, Bhagalpur- 812007, India
E-mail: tkgzool@yahoo.co.in

Received: 14.08.2010, Accepted: 28.10.2010

Abstract
Oxygen uptake (VO_2) through the gills in relation to body weight has been studied in *Notopterus notopterus* at 24.0±1.0ºC under continuous water flow system. With gradual increase in body weight from 5.10 to 122.33 g, the oxygen uptake increased from 1.164-3.975 $mlO_2.h^{-1}$. The log-log plot between the oxygen uptake per unit time and body weight gave a straight line with the slope ‘b’ value of 0.421. The relationship between the two variables was found to be highly significant ($r= 0.986$; $p<0.001$). However, the weight specific oxygen uptake decreased from 228.36 to 32.49 with increase in body weight from 5.10 to 122.33 g. A straight line with slope ‘b’ value of -0.629 was obtained when plotted on log-log coordinates, showing a highly significant negative correlation ($r= 0.985$; $p<0.001$).

***Key words*:** Aquatic oxygen uptake, Body weight, *Notopterus notopterus*, air-breathing fish

Introduction
The rate of metabolism in fishes is determined by measuring the oxygen uptake, which directly depends on various extrinsic and intrinsic factors *viz*., body weight, developmental stages and activity of the fish etc. (Fry, 1957; Prosser, 1961; Dejours, 1975). Activity of a fish is one of the most important factors according to Fry (1971) and can be measured as routine metabolic rate (RMR), Standard metabolic rate (SMR) and active metabolic rate (AMR). Zeuthen (1953) suggested a slope value of 0.78 for various fish species in relation to body weight / size. Moss and Scott (1961) and Beamish (1964) determined the specific metabolic rate in relation to body weight in various species of fishes. Oxygen uptake in relation to body weight have been studied in some purely aquatic breathing Indian fishes by Roy and Munshi (1984), Kunwar *et al*. (1989), Ojha and Singh (1981), Singh *et al*. (1991) and Jha *et al*. (2008). Attempts have also been made to determine the relationship between body weight and aquatic oxygen uptake in some Indian air-breathing fishes *viz*., *Anabas testudineus* (Munshi and Dube, 1973), *Clarias batrachus* (Munshi *et al*., 1976), *Colisa fasciatus* (Ojha *et al*., 1977), *Channa punctatus* (Hakim *et al*., 1983), *Anabas testudineus* and *Channa punctatus* (Pandit, 2001) etc. Observation on bimodal oxygen uptake in *Notopterus chitala* have been made by Ghosh *et al*. (1986).

However, so far no attempt has been made to study the relationship between the rate of aquatic oxygen uptake and body weight in *Notopterus notopterus*. The present work is an attempt to establish the relationship between oxygen uptake and the body weight in the Indian Freshwater dual breathing featherback, *Notopterus notopterus*.

Notopterus notopterus, locally known as Kapti, occurs in fresh and brackish waters of India and Malaya. It is usually found in clean streams, tanks, large lakes and reservoirs and thrives well in lentic waters. It is used as food fish. This fish is relished both fresh and dried state (CSIR, 1962). As the fish is carnivorous, it can only be cultivated with large fishes.

Materials and methods

Live specimens of different weight groups of *Notopterus notopterus* were collected from the local fish market and through fishermen. They were brought to the Departmental Aquarium House and were maintained in large plastic pools having chlorine free tap water (water temperature 23.0-25.0°C; pH 7.2-7.4) for about two weeks with aerator on during this period.

To measure the rate of oxygen uptake, a cylindrical glass respirometer similar to that used by Ghosh and Munshi (1987) was used, in which continuous flow of water was maintained. As per the size of the fish, the cylindrical glass respirometer of different capacity was used to avoid stress to the fish during experimentation. The respirometer was connected to a large constant level water tank having chlorine free tap water to maintain the water flow under constant hydrostatic pressure (Fig. 1). The fishes were acclimatized in the respirometer for about two hours before experimentation. The respirometer was covered over with a black cloth to avoid visual disturbances. The flow of water through the respirometer was adjusted according to the size of the fish so that the fish remains free from any stress.

Inspired and expired water samples were collected in conical flasks connected at both the ends of the respirometer. The concentration of the dissolved oxygen content in the sample water was determined using Winkler's volumetric method (Welch, 1948). Oxygen uptake per unit time ($mlO_2.h^{-1}$) and per unit body weight ($mlO_2.kg^{-1}.h^{-1}$) was calculated by the differences in the dissolved oxygen levels between inspired and expired water, rate of flow of water through the respirometer and the body weight of the fish. An average value, out of the three readings taken at every half an hour interval was calculated.

Results

Aquatic oxygen uptake per unit time ($mlO_2.h^{-1}$)

In *Notopterus notopterus*, the oxygen uptake gradually increased from 1.164 to 3.975 $mlO_2.h^{-1}$ with increase in body weight from 5.10 to 122.33 g (Tab. 1). The log-log plot of the oxygen uptake in relation to body weight gave a straight line with the slope 'b' value of 0.421, when the different scores were fitted by the least square method (Tab. 2, Fig. 2). The two variables indicated highly significant correlation ($r=0.986$; $p<0.001$). The estimated value of oxygen uptake for 1.0 g *Notopterus notopterus* i.e., the intercept value was found to be 0.508 (Tab. 2, Fig. 2). The estimated values of oxygen uptake per unit time for 1.0, 10.0, 100.0 and 1000.00 fishes were calculated to be 0.508, 1.339, 3.533 and 9.320 respectively (Tab. 3).

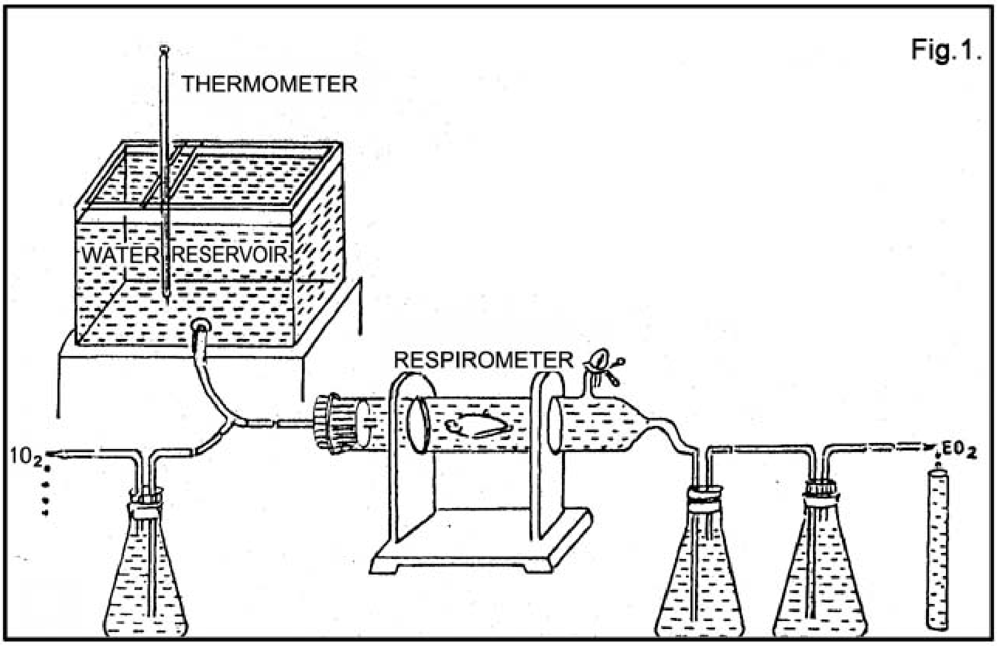

Figure 1. Experimental setup for the measurement of aquatic oxygen uptake in *Notopterus notopterus*.

Table 1. The rate of aquatic oxygen uptake (VO_2) of *Notopterus notopterus* against body weight at 24.0±1ºC.

Body Weight (g)	Oxygen Consumption (VO_2)	
	$mlO_2.h^{-1}.fish^{-1}$	$mlO_2.kg^{-1}.h^{-1}$
5.10±0.100	1.164±0.388	228.366±55.909
10.20±0.283	1.236±0.397	188.833±59.024
15.70±0.300	1.495±0.274	95.200±0.054
21.50±0.000	1.749±0.000	81.340±0.000
25.10±0.360	1.851±0.095	74.367±4.692
33.60±0.360	2.418±0.040	71.970±1.026
49.00±0.000	2.685±0.000	54.790±0.000
90.00±0.000	3.405±0.069	37.800±0.068
117.50±0.000	3.781±0.180	32.100±2.616
122.33±0.289	3.975±0.298	32.490±1.656
Average : 49.003±0.282	2.376±0.218	89.726±15.631

Table 2. The Allometric equation, Intercept ‘a’, Regression coefficient ‘b’ and Correlation coefficient ‘r’ to show the relationship between oxygen uptake VO_2 ($mlO_2.h^{-1}.fish^{-1}$ and $mlO_2.kg^{-1}.h^{-1}$) and body weight in *Notopterus notopterus*. Their 95% C.L. are also given.

Oxygen Uptake (VO_2)	Allometric equation $y = aw^b$	Intercept ‘a’		Slope ‘b’		Correlation coefficient ‘r’
		Value	95% C.L.	Value	95% C.L.	

VO_2 ($mlO_2.h^{-1}.fish^{-1}$)	Log VO_2 = log 0.508+0.421. log W Or, VO_2=0.508. $W^{0.421}$	0.508	0.413 0.624	0.421	0.364 0.478	0.986 ($p<0.001$)
VO_2 ($mlO_2.kg^{-1}.h^{-1}$)	Log VO_2 = log 630.897 – 0.629. log W Or, VO_2=630.897. $W^{-0.629}$	630.897	457.575 869.871	-0.629	-0.718 -0.539	0.985 ($p<0.001$)

Table 3. Statistically estimated data of aquatic oxygen uptake VO_2 ($mlO_2.h^{-1}.fish^{-1}$ and $mlO_2.kg^{-1}.h^{-1}$) for 1.0, 10.0, 100.0 and 1000.0 g of *Notopterus notopterus* based on regression analysis using least square method. Their 95% confidence limit are also given.

Body Weight	**Oxygen Uptake (VO_2)**			
(g)	Value ($mlO_2.h^{-1}.fish^{-1}$)	95% C.L.	Value ($mlO_2.h^{-1}.fish^{-1}$)	95% C.L.
1	0.508	0.413/0.624	630.897	457.575/869.871
10	1.339	0.955/1.879	148.346	87.569/251.307
100	3.533	2.207/5.656	34.881	16.759/72.603
1000	9.320	5.102/17.026	8.202	3.207/20.975

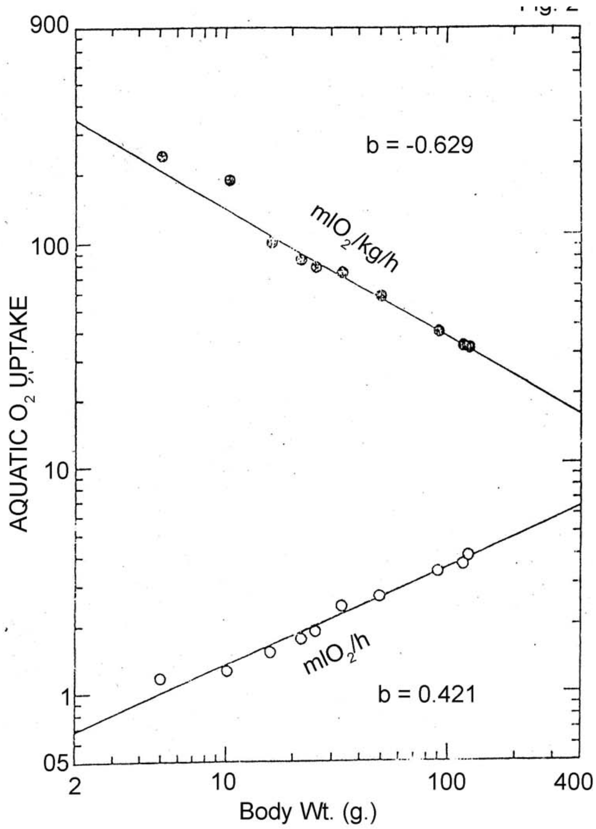

Figure 2. Log/log plots showing relationship between body weight and oxygen uptake per unit time ($mlO_2.h^{-1}.fish^{-1}$) and body weight and weight specific oxygen uptake ($mlO_2.kg^{-1}.h^{-1}$) at 24.0±1.0°C in *Notopterus notopterus*.

***Aquatic Oxygen Uptake per Unit Body Weight* ($mlO_2 . kg^{-1}.h^{-1}$)**

The weight specific oxygen uptake in *Notopterus notopterus* decreased from 228.366 to 32.490 with increase in body weight from 5.10 to 122.33 g (Tab. 1). A straight line with slope 'b' value of –0.629 and intercept 'a' value of 630.897 was obtained when the data for weight specific oxygen uptake rate were plotted against body weight on log-log co-ordinates (Tab. 2, Fig. 2). There exists a highly significant but negative correlation between the two variables ($r=0.985$; $p<0.001$). The estimated values of weight specific oxygen uptake for 1.0, 10.0, 100.0 and 1000.0 g fishes were found to be 630.897, 148.346, 34.881 and 8.202 respectively (Tab. 3).

Discussion

Measurement of oxygen uptake in an organism depends upon various abiotic and biotic factors (Imabayashi and Takahashi, 1987). Among these, body weight plays a significant role and it has been observed that in most of the fishes, the rate of oxygen consumption in per unit time ($mlO_2.h^{-1}$) increased with gradual increase in body weight. However, the weight specific oxygen consumption ($mlO_2.kg^{-1}.h^{-1}$) has shown decreasing trend, with increase in body weight.

Several workers have determined slope 'b' values to establish the relationship between oxygen uptake and the body weight. Smith (1935 a, b), Job (1955), Winberg (1956) and Paloheimo and Dickie (1965) have observed and stated differences in the slope 'b' values in different fish species varying between 0.78 to 0.85. Prosser (1961) determined the slope values and shown to range from 0.67 to 1.0. Barlow (1961), Ruhland (1965) and Morris (1967) reported a rather low slope 'b' value in the range of 0.5.

In the present study, the relationship between the oxygen uptake per unit time and per unit body weight in *Notopterus notopterus* gave a straight line when plotted on log-log graph. The slope 'b' was calculated to be 0.421 within the body weight range of 5.10 to 122.33 g. This value is lower than most of the purely water breathing fishes *viz*., 0.662 in *Mystus cavasius* (Ojha and Singh, 1981), 0.728 in *Labeo bata* (Sinha, 1983), 0.796 in *Cirrhinus mrigala*, (Roy and Munshi, 1984), 0.851 in *Labeo rohita* and 0.747 in *Catla catla* (Kunwar *et al*., 1989). However, the slope 'b' value 0.421 for *Notopterus notopterus* was slightly lower but closer to the values for juveniles of *Catla catla* (0.561) and *Labeo rohita* (0.538) (Jha *et al*., 2008).

Similarly, the estimated slope value (b) showing the relationship between the oxygen uptake and body weight of *Notopterus notopterus* is also lower than the values reported for many air-breathing fishes. In *Heteropneustes fossilis* the oxygen consumption through gills increased by a power function of 0.799 (Munshi *et al*., 1978). Hakim *et al*. (1983) in *Channa punctatus* estimated a slope value of 0.629. Although, the present value is less than almost all the reported species of adult air-breathing fishes, yet, it is closer to the value for juveniles of *Heteropneustes fossilis* (0.475) (Munshi *et al*., 1978). The difference in slope value of different fish species seems to be due to different growth pattern, stages of their life cycle, physiological condition of fish and changes in feeding behaviour etc. (Smith, 1935 a, b; Kamler, 1972).

Generally, the weight specific oxygen consumption decreases with unit increase in body weight when the computed slope 'b' value is less than 1. The slope 'b' for weight specific oxygen uptake in *Notopterus notopterus* was –0.629. Such a decreasing trend was also reported by various other workers *viz*., Munshi and Dube (1973) in *Anabas testudineus*, Munshi *et al*. (1978) in *Heteropneustes fossilis*, Hakim *et al*. (1983) in *Channa punctatus*, Kunwar *et al*. (1989) in *Labeo rohita* and *Catla catla*, Pandit (2001) in *Anabas testudineus* and *Channa punctatus* etc. According to Prigogine and Wiame (1946) the weight specific oxygen consumption can only decrease with gradual increase in body weight. This is probably due to opportunities for lower costs, changes in skeletal structures, economy of food utilization etc. (Jones, 1972; Schmidt-Neilson, 1984).

The estimated value of aquatic oxygen uptake per unit time for 1.0 g fish or the intercept 'a' value of *Notopterus notopterus* was found to be 0.508 which is higher than the values reported for many purely water breathing fishes *viz*., 0.321 in *Labeo rohita* (Kunwar *et al*., 1989), 0.447 in *Labeo bata* (Sinha, 1983), 0.321 in *Glossogobius giuris* (Singh and Munshi, 1985) 0.263 in *Catla catla*, (Kunwar *et al*., 1989) etc., but lower than 0.532 in *Mystus cavasius* (Ojha and Singh, 1981).

The value is also higher than that of many air-breathing fishes *viz*., 0.215 in *Heteropneustes fossilis* (Munshi *et al*., 1978) and 0.394 in *Channa gachua* (Ojha *et al*., 1978). However, this value is slightly lower but closer to 0.526 in *Anabas testudineus* (Munshi and Dube, 1973). This indicates that the rate of oxygen uptake of *Notopterus notopterus* occupies an intermediate position in comparision to purely aquatic breathing fishes and other air-breathing fishes.

Acknowledgements

The authors thankfully acknowledge the financial support to this work by Indian Council of Agricultural Research [ICAR (No. 4 (5)/89-ASR-I)] and Council of Scientific and Industrial Research [CSIR (No. 37 (793)/91-EMR-II], New Delhi.

References

Barlow, G.W. 1961. Intra and inter specific difference in rate of oxygen consumption in gobid fishes of the genus *Gillichthys*. *Biol. Bull.* ***121*****:** 209-229.

Beamish, F.W.H. 1964. Respiration of fishes with special emphasis on standard oxygen consumption. II. Influence of weight and temperature on respiration of several species. *Can. J. Zool.* ***42*****:** 177-188.

CSIR 1962. *The wealth of India: Raw materials, Vol IV Fish and Fisheries*. Publ. CSIR, New Delhi. 132 p.

Das, P.C., S. Ayyappan and J.K. Jena 2003. Oxygen consumption pattern of fingerlings of Indian major carps, *C. catla* (Ham.), *L. rohita* (Ham.) and *Cirrhinus mrigala* (Ham.). *J. Inland Fish. Soc.* India. ***35*****(*****2*****):** 45-49.

Dejours, P. 1975. *Principles of comparative respiratory physiology*. North-Holland Publishing Company, Amsterdam. 253 p.

Fry, F.E.J. 1957. The aquatic respiration of fish. In *The Physiology of Fishes*. Vol. 1, (Ed. M.E. Brown). Academic Press, New York. pp 1-63.

Fry, F.E.J. 1971. The effect of environmental factors on the physiology of fish. In *Fish Physiology* (Eds. W.S. Hoar and D.J. Randall), Academic Press, New York. ***6*****:** 1-98.

Ghosh, T.K. and J.S.D. Munshi 1987. Bimodal oxygen uptake in relation to body weight and seasonal temperature of an air-breathing climbing perch, *Anabas testudineus* (Bloch). *Zool. Beitr. N.R.* ***31*****(*****3*****):** 357-364.

Ghosh, T.K., A. Moitra, G.K. Kunwar and J.S.D. Munshi 1986. Bimodal oxygen uptake in a freshwater air-breathing fish, *Notopterus chitala*. *Jap. J. Ichthyol.* ***33*(*3*):** 280-285.

Hakim, A., J.S.D. Mushi and G.M. Hughes 1983. Oxygen uptake from water through the respiratory organs in *Channa punctata* (Bloch) in relation to body weight. *Proc. Ind. Natn. Sci. Acad. B.* ***49*(*2*):** 73-85.

Imabayashi, H. and M. Takahashi 1987. Oxygen consumption of post larval and juvenile Red Sea Bream, *Pagrus* major with special reference to group effect. *J. Fac. Appl. Biol. Sci.* ***26*:** 15-21.

Jager, S.D. and W.J. Dekkers 1975. Relationship between gill structure and activity in fish. *Neth. J. Zool.* ***25*(*3*):** 276-308.

Jha, K.K., P.K. Roy and T.K. Ghosh 2008. Oxygen uptake in the early developmental stages of two Indian major carps, *Catla catla* (Ham.) and *Labeo rohita* (Ham.) in relation to body weight. *J. Inland Fish. Soc.* India. ***40*(*2*):** 7-12.

Job, S.V. 1955. The oxygen consumption of *Salvelinus fontinalis*. *Univ. Toronto Biol. Ser.* **(*G*):** 1-39.

Jones, J.D. 1972. *Comparative physiology of Respiration*. Edwards Arnold, London. pp. 22-33.

Kamler, E. 1972. Respiration in carps in relation to body size and temperature. *Pol. Arch. Hydrobiol.* ***19*:** 325-331.

Kunwar, G.K., A. Pandey and J.S.D. Munshi 1989. Oxygen uptake in relation to body weight of two freshwater major carps *Catla catla* (Ham.) and *Labeo rohita* (Ham.). *Ind. J. Anim. Sci.* ***59*(*5*):** 621-624.

Morris, R.W. 1967. High respiratory quotients of two species of bony fishes. *Physiol. Zool.* ***40*:** 409-423.

Moss, D.D. and D.C. Scott 1961. Dissolved oxygen requirements of three species of fish. *Trans. Am. Fish. Soc.* ***90*:** 377-393.

Munshi, J.S.D. and S.C. Dube 1973. Oxygen uptake capacity of gills in relation to body size of air-breathing fish, *Anabas testudineus* (Bloch). *Acta. Physiol. Acad. Hungaricae.* ***44*:** 113-123.

Munshi, J.S.D., A.L. Sinha and J. Ojha 1976. Oxygen uptake capacity of gills and skin in relation to body weight of the air-breathing fish, *Clarias batrachus*. *Acta. Physiol., Acad. Sci. Hung.* ***48*:** 23-33.

Munshi, J.S.D., B.N. Pandey, P.K. Pandey and J. Ojha 1978. Oxygen uptake through gills and skin in relation to body weight of an air-breathing siluroid fish, *Saccobranchus* (=*Heteropneustes*) *fossilis* (Bloch.). *J. Zool. Lond.* ***184*:** 171-180.

Ojha, J. and R. Singh 1981. Oxygen uptake in relation to body weight of the freshwater catfish, *Mystus cavasius* (Ham.). *Indian J. Expt. Biol.* ***19*:** 126-129.

Ojha, J., O.P. Dandotia and J.S.D. Munshi 1977. Oxygen consumption of an amphibious fish, *Colisa fasciatus*. *Hydrobiol.* ***24*(*4*):** 547-553.

Ojha, J., O.P. Dandotia, A.K. Patra and J.S.D. Munshi 1978. Bimodal oxygen uptake in relation to body weight in a freshwater murrel, *Channa* (=*Ophiocephalus*) *gachua*. *Z. Tierphysiol.* ***40*:** 57-66.

Paloheimo, J.E. and L.M. Dickie 1965. Food and growth of fishes. II. Effects of food and temperature on the relation between metabolism and body weight. *J. Fish. Res. Bd. Can.* ***23*:** 869-908.

Pandit, D.N. 2001. *Studies on the oxygen requirement of early developmental stages of certain air-breathing teleosts in relation to their transportation*. T.M. Bhagalpur University, Bhagalpur. 83 p. (Ph.D. Thesis)

Prigogine, J. and J.M. Wiame 1946. Biologic at thermadynamique des phenomenas irreversible. *Experimentia* (Basal) ***2*:** 451-453.

Prosser, C.L. 1961. Oxygen, respiration and metabolism. In *Comparative Animal Physiology*, (Eds. C.L. Prosser and F.A. Brown Jr.). W.B. Saunders and Company, Philadelphia, London. pp.153-190.

Roy, P.K. and J.S.D. Munshi 1984. Oxygen uptake in relation to body weight and respiratory surface area in *Cirrhinus mrigala* (Ham.) at two different seasonal temperatures. *Proc. Ind. Natn. Sci. Acad. B* ***50*(*4*):** 387-394.

Ruhland, M.L. 1965, Etude comparative de la consommation d' chez differentes especes de poissons teleosteans. *Bull. Soc. Zool.*, France. ***90*:** 347-353.

Schimidt-Neilson, K. 1984. *Scaling: why is animal size so important*? Cambridge University Press, Cambridge.

Singh, D.K., D.N. Singh and J.S.D. Munish 1991. Oxygen uptake in relation to body weight in *Rita rita* (Ham.) (Bagridae, Pisces) at two different seasonal temperature. *J. Freshwater Biol.* ***3*(*1*):** 15-21.

Singh, O.N. and J.S.D. Munshi 1985. Oxygen uptake in relation to body weight, respiratory surface area and group size in a freshwater goby, *Glossogobius giuris* (Ham.). *Proc. Ind. Natn. Sci. Acad. B.* ***51*:** 33-40.

Sinha, S.K. 1983. *Biology of Labeo bata* (*Ham.*). T.M. Bhagalpur University, Bhagalpur, India. 305 p. (Ph.D. Thesis)

Smith, H.W. 1935a. The metabolism of lung fish I. General consideration of the fasting metabolism on active fish. *J. Cell. Comp. Physiol.* ***6*:** 43-67.

Smith, H.W. 1935b. The metabolism of lung fish II. Effect of feeding meat on the metabolism rate. *J. Cell. Comp. Physiol.* ***6*:** 335-349.

Welch, P.S. 1948. *Limnological methods.* McGraw Hill, New York.

Winberg, G.G. 1956. Rate of metabolism and food requirements of fishes. *Fish. Res. Bd. Can.*, trans. Ser. no. 194.

Zeuthen, E. 1953. Oxygen uptake in relation to body size in organisms. *Rev. Biol.* ***28*:** 1-12.